Teachers' perspectives and practices on biodiversity web portals as an opportunity to reconnect education with nature

TEACHERS' PERSPECTIVES AND PRACTICES ON BIODIVERSITY WEB PORTALS AS AN OPPORTUNITY TO RECONNECT EDUCATION WITH NATURE

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Summary

Biodiversity loss is a complex issue, and a risk that education cannot overlook. Teachers play a crucial role in how biodiversity, and in particular local biodiversity, is understood. To provide insight on how to improve communication on the subject, we investigate teachers' perspectives and social representations about biodiversity, their fluency on the internet, familiarity with biodiversity web portals, and perceived technology pedagogical usefulness. A sample of 243 K-12' school-teachers of multiple scientific domains, from eight Azorean Islands answered an online survey, including three free-word association tests using inductive terms such as 'internet', 'biodiversity' and 'familiar biodiversity portals'. Overall, they failed to incorporate the multidimensionality of the biodiversity concept (including natural science teachers), or show technological fluency, and tended not to use biodiversity web portals as tools to engage students in teaching activities. Our results indicate that teachers' perspectives about biodiversity need to be broadened and improved, and that it is worth exploring whether ICT represents a window of opportunity to do so. As an example, biodiversity web portals, widely recognized as trustworthy information repositories, may be used to engage teachers in this endeavour.

Keywords: nature experience, place-based education, digital education, biodiversity education, Azores, ICT, social representations, free-word association

INTRODUCTION

The loss of biodiversity, at all levels, including species extinctions and functional and phylogenetic diversity erosion, can lead to a breakdown of ecosystems (IPBES 2019, Rockström et al. 2009). The characteristics of this risk, including its high probability of occurrence and potential damage, are well-known (Liu et al. 2015), but barely recognized by the general public, possibly due to its complexity, ambiguity, and insidious nature (Renn 2008).

Thus, effective communication of biodiversity loss to society is not as efficient in comparison to other environmental problems such as climate change (Arroz et al. 2016). Evidence of communication failure includes the poor progress on the 20 ‘Aichi Targets’ of the Strategic Plan on Biodiversity 2011–2020 of the Convention on Biological Diversity (Díaz et al. 2019) and the need for the global coalition for biodiversity launched by the European Commission in March 2020.

The lack of audibility regarding biodiversity loss has not been accompanied by research on the reasons underling people's detachment from this issue or on understanding their perspectives on biodiversity (but see Fischer & Young 2007; Dikmenli 2010), yet individuals can use biodiversity with different scientific, political, and symbolic meanings, depending on the context and timing; both knowledge and value associated with biodiversity vary. Investigating people´s perspectives on biodiversity, including their arguments in order to be able to counter them, would thus allow expanding knowledge and raising biodiversity awareness.

Education is key because it constitutes a beneficial instrument for conceptual change, ensuring the development of skills and the confidence to protect biodiversity (Edison 2017). However, this effectiveness requires teachers' perspectives to be aligned with the curricula and with national and international goals for biodiversity and nature conservation. Although there is little research about teachers' perspectives on biodiversity, teachers are aware of its inherent complexity and express concern about biodiversity loss (Gayford 2000). Despite that, given time constraints of covering the entire curriculum, teachers fail to seize opportunities to explore essential links on biodiversity, which would enable students to relate knowledge and understanding with behaviours and attitudes (Gayford 2000).

The disconnection between people and nature is considered one of four major challenges in biodiversity education (Navarro-Perez & Tidball 2012), however, it is not limited to school settings: due to its unpredictable consequences, this ‘extinction of experience’ (Miller 2005, Gaston & Soga 2020), is an actual challenge for society.

The growing importance of technology has certainly contributed to withdrawal from nature (Hasebrink 2009, Brennen & Kreiss 2016), and led to a concept of ‘technological nature’, comprising the technologies that, in various ways mediate, augment, or simulate the natural world (Kahn et al. 2009). However, the relationship between this technological nature and ‘real nature’ is complex: the former can simultaneously dispute and remove space from the relationship with real nature (e.g. Pergams & Zaradic 2006), or constitute an awareness tool for nature conservation and biodiversity loss (e.g. Selby & Kagawa 2018).

Thus, a new realm has emerged, between teaching young people and creating new pedagogical opportunities that take advantage of digital information and interactive communication technologies (ICT) (Navarro-Perez & Tidball 2012), since these are particularly popular amongst the new generations (Kouper 2010). There has been an increase in biodiversity education methods like experiential learning (Fattorini et al. 2017), inquiry-based learning or place-based learning (Barnes et al. 2019), and digital technologies connecting students to living environments (Yli-Panula et al. 2018). When adjusted to teachers' and students' interests, ICT can enhance learning techniques allowing effective and efficient communication skills, knowledge, and attitudes in support of biodiversity conservation goals (Jacobson et al. 2006, Ferreira et al. 2015).

Little is known about the experiences of teachers as internet users and what they think about it (but see Lagarto & Lopes 2018). For instance, there are several digital teaching platforms for biodiversity (e.g. biodiversity4all [Inaturalist], Naturdata, Biodiversity Learning Platform), but studies on their impacts on teaching and learning are scarce; besides, the information sources provided by these platforms are not always validated and updated. On the other hand, several biodiversity web portals play a central role in the exchange of accurate information, mainly for cooperation and exchanging knowledge among researchers (Borges et al. 2010). For instance, an Academic Google search on 'GBIF' returned 25 300 results, and on 'Atlas of Living Australia' 2 800, while the more generic concept 'Biodiversity Portal' returned 690 results. When adding the term 'teaching' to each search, the number of citations fell to less than 10% of their original values, the fall suggesting that portals represent a resource much-underused by the educational community. We did not find any studies addressing biodiversity teaching

using web portals. The educational potential of web portals becomes even more evident when local communities benefit from the existence of portals specialized in local biodiversity, which can be mobilized for place-based learning and allow an efficient dialogue between the digital and real 'versions' of biodiversity.

It is therefore relevant to understand how teachers in a region like the Azores value ICT as a communication strategy, how comfortable they feel with digital tools, and how and if they mobilize them in teaching biodiversity. We formulated the following research questions: (1) How do teachers incorporate the ICT in their work? What are their thoughts about the internet? And how do they use it? (2) How do teachers perceive biodiversity? What aspects do they emphasize? What are their conceptual gaps? What helps explain their representations? (3) To what extent are biodiversity portals a relevant tool for the teaching-learning process? How do teachers envisage their usefulness and contributions?

METHODOLOGY

Study area and participants

The Azores is a Portuguese archipelago located in the North Atlantic between 37º–40°N and 25º–31°W. It consists of nine volcanic islands with 242,723 inhabitants, 122,300 of whom re professionally active, 40% of them with a secondary or higher education degree (SREA 2019). This region is known for its high biodiversity importance in the context of the Macaronesia hotspot (Myers 2000; Borges *et al*. 2010).

From August to October 2019, 243 public school teachers (197 female; 43 male; 3 unknown gender), between the ages of 29 and 67 years (mean 46.2 SD ± 6.8 years), with

120 an average work experience of 22 years (SD ± 7 years), working on eight Azorean islands,
121 completed an online survey (Table S1). About half of the participants (53%) were native
122 to the Azores (Table S1). This sample represents 6% of the total 4 635 Azorean teachers,
123 with significant differences of gender (3194 female; 1044 male; Chi^2 (1df) = 5.58; p
124 <0.002), age (49 ± 7.5 years; Chi^2 (3df) = 30.49; p <1.09 E-06) and teaching experience
125 (18 ± 8 years; Chi^2 (5df) = 91.55; p <3.18 E-18).

126 *Instrument and procedure*

127 The online survey by questionnaire (Appendix S0) comprised: (i) three free word
128 association tests regarding the inductive terms 'internet', 'biodiversity', and 'a familiar web
129 portal related to biodiversity and/or nature conservation' to reveal the cognitive structures
130 of the collective representations (Moscovici 1991, Abric 2003); (ii) 20 questions about the
131 use of ICT/internet and web portals as educational resources; (iii) the Nature Exposure
132 Scale (NES), a 5-point Likert-type instrument, from 1 (minimum) to 5 (maximum),
133 measuring the representations of 'direct physical and or sensory contact with the natural
134 environment' (Kamitsis & Francis 2013, p.137). The scale has four items: two assessing
135 exposure to nature in everyday life, and two in rich environments. The scale shows
136 acceptable psychometric qualities; Appendix S4); and (iv) nine socio-demographic
137 questions about age, gender, place of birth, residence, educational background, years of
138 teaching experience, teaching subject, teaching educational level, teaching school.

139 Upon approval of the study by the Azores University Ethics Committee, all teachers
140 working in Azorean public schools received a link to an anonymous Google Forms
141 questionnaire through an official e-mail by the Education Services.

142 *Data analysis*

Data were downloaded from Google Forms into an Excel file, and the resulting database was exported to different software according to the data properties and the research questions. All evocations were translated from Portuguese to English.

Descriptive statistical analysis was conducted for all nominal and ordinal variables; the total sum of values was also calculated for NES scale.

The study used a multimethod approach to explore the free word association results in order to identify the structure of social representations (SRs), deepen their understanding and strengthen their validity (Abric 2003). The tests started with the analysis of the 'semantic field', calculating the indexes of Fluidity (total number of evocations; n_F), Amplitude (number of different evocations; n_A) and Richness (ratio between them) (Poelsch & Ribeiro 2010).

Data were also subject to a prototypical analysis (e. g. Vale & Maciel 2019) to reveal a hypothetical organization of SR contents resulting in the division of evoked terms into four quadrants, according to the crossover of frequency and order of evocation (Abric 2003): the first quadrant, upper left, has words with high frequency and low evocation order, and aggregates the central core of the SR; the second quadrant, upper right, has words with high frequency and high evocation order, and completes and protects the SR core; the third quadrant, lower left, has words with low frequency and evocation order, showing possible alternatives to the core SR or complementing it; and the fourth quadrant, lower right, has words with low frequency and high evocation order, exhibiting more transitional elements. We calculated threshold values according to the recommendations of Wachelke & Wolter (2011). The Ellegard's R_n index compares the resemblance between

the lexicons of two semantic fields organized by predictive variables (e.g. older vs younger); it considers the number of words common to the two semantic fields, divided by the square root of the product of the amplitude of the two fields, and varies from 0 to 1 (Di Giacomo 1986).

The same data were then subjected to a similarity analysis to test and consolidate the SR. This analysis is based on graph theory and identifies the organization of the various elements of the representation through the degree of connectivity between the evoked terms, resulting in a maximum tree, which indicates the visual distribution of the different sized categories and micro-categories, and their relationship with the core representation (Alves-Mazzoti 2007).

Data of the free word association tests were processed using the freeware program IRAMUTEQ (Ratinaud 2009, Camargo & Justo 2013).

RESULTS

How do teachers incorporate the ICT in their work? What are their thoughts about the internet? And how do they use it?

Using ‘internet’ as an inductive term, the 243 teachers produced 1064 evocations, 239 of which were different words, 213 repeated words; 123 words were mentioned only once and thus disregarded from the analysis (Appendix S1).

The central core of the prototypical analysis of ‘internet’, corresponding to 51% of the total evocations (Fig. 1a), revealed a kind of ‘global information database’, that people access

186 to search, communicate, and work with, individually or collaboratively, through Google,
187 social networks or e-mail. The contrast zone shows the risks associated with web surfing.
188 Most terms used by teachers tended to describe the 'what' and 'how' of the internet, while
189 their qualifying properties, such as 'fast', 'ease', 'fun' were distributed across the various
190 quadrants (Fig. 1a).

191 Fig. 1

192 Bearing in mind that the content of the central core of the prototypical analysis constitutes
193 only a hypothesis of the centrality of SR (Abric 2003), the subsequent similarity analysis
194 allowed us to understand the groupings and the organization of the various elements
195 identified, and thus to capture the meaning of the representation (Fig. 1b).

196 The word 'internet' elicited three groups or stars, centralized around the terms
197 'information', 'search' and 'knowledge' (Fig. 1b). 'Information' took the lead both in terms
198 of frequency and number of points of co-occurrence (*fc*, frequency of co-occurrence). A
199 series of terms revolved around 'information', even though its meaning is in close
200 relationship with 'communication'. The internet's global character, contents, means, and
201 risks associated with this repository and its sharing were emphasized. Furthermore, the
202 quality of the surfing experience was highlighted in an autonomous branch, congregating,
203 'speed', 'ease' and 'convenience'. Enjoying a strong co-occurrence with 'information'
204 (*fc*=39), the term 'search' was connected with different devices, including search engines,
205 social networks, and various applications. It related to the third star, 'knowledge' (*fc*=27),
206 that associated different ways to understand and experience the world: scientific, ludic
207 and virtual.

Our analysis shows a collective and homogeneous representation of the 'internet', since we did not find significant differences with most tested predictors (Appendix S1). However, natural science teachers and male teachers, in particular, produced higher average numbers of words (Appendix S1).

The surveyed Azorean teachers were commonly using the internet: 216 (90%) more than once a day and with multiple hardware ICT tools to access it (Fig. S1a), reflecting a routine use of internet, which has most likely increased due to mandatory confinement and telework after the pandemic of COVID-19.

Among teachers' activities performed online, there were two non-mutually exclusive cores: one revealed a personal pattern of internet use, grouped around 'getting information' (n=165), also comprising 'keep updated on the news' and 'keep in contact with friends'; the other, revealed a professional pattern, aggregated around 'class preparation' (n=168), and including 'social networking', 'file-sharing' or 'researching in books and science texts'. The use of e-mail was common among almost all teachers (96%) (Fig. S1b, 1c).

How do teachers perceive biodiversity? What aspects do they emphasize? What are their conceptual gaps? What helps explain representations?

In a free-word association on the concept of 'biodiversity', 240 teachers mentioned 857 words, 90 of which were different. The evocation frequencies varied between one (35 single words) and 86.

The number of teachers' evocations concerning 'biodiversity' was much lower than that relating to 'internet', although it remained quite homogeneous and weak (Table 1). The

amplitude of the semantic fields differed only according to gender (Chi^2 (1df) 17.65; $p<0.000$) and scientific teaching area (Chi^2 (1df) 18.41; $p<0.000$), where male teachers and teachers of exact and natural sciences showed greater erudition. The same groups also showed significant differences in terms of fluidity, with female teachers (Chi^2 (1df) 5.82; $p<0.05$) and teachers of other scientific areas (Chi^2 (1df) 5.06; $p<0.05$) presenting less extensive lexicons. Thus, the less rich – or more stereotyped – semantic fields were associated with the same groups of teachers.

Ellegard's Rn index (cf. Table 1) comparing the degree of similarity between the semantic fields of the tested predictors suggests that gender (Rn=0.19) and use of web portals concerning biodiversity (Rn=0.19) differentiated information about biodiversity more than any other predictor.

Table 1

The prototypical analysis revealed the content of the SR of biodiversity for the 234 Azorean teachers, presenting a descriptive central core mentioning ‘diversity’, ‘life’ and ‘nature’. Among the three levels of the concept recognized by the Convention on Biological Diversity (CBD), the focus was on the specific level (e.g. fauna, flora, species), while the genetic and ecosystem levels were practically absent (Fig. 2a; Appendix S2). Complementing the central core there was also the recognition of the need of environmental conservation, underlined by terms such as ‘risk’, ‘planet’, ‘preservation’ and ‘sustainability’.

Fig. 2

The first periphery quadrant shows the terms ‘ecosystems’ and ‘equilibrium’, supplementing the specific level with the relationships among living beings (Fig. 2a). The contrast zone focused on the geographical context – the Azores, a biodiversity hotspot, and its ‘endemic species’. Furthermore, it contained evocations about the scientific background of biodiversity (‘sciences’, ‘biology’). It is noticeable that ‘birds’ are the only taxonomic class mentioned (Fig. 2a). The recognition that biodiversity is crucial for the ‘survival’ and the ‘future’ of ‘humankind’ emerged only in the second periphery that aggregates the terms evoked fewer times and with lower evocation orders (Fig. 2a).

The similarity analysis of the same lexicon revealed three clusters, represented by nature preservation, ecosystem diversity, and fauna and flora, all bearing strong co-occurrence links (*fc*=24 and *fc*=28, respectively) (Fig. 2b). The ‘diversity’ cluster had the highest number of co-occurrence’ links. The metaphor that emerged from the semantic relationship between the terms that composed it leads us to a global ecosystem, Gaia, which encompasses not only the species and their habitats but also the knowledge produced about them and the need to ensure life sustainability (Fig. 2b). In the second cluster, the main idea was the preservation of nature and the environment, given human responsibility to ensure the necessary balance for species and planetary survival (Fig. 2b). The third cluster was more focused on elements such as living beings, their habitats and resources needed. However, there were no evident relationships among them, hence the link between these elements and the second cluster, since it connected with ‘nature’ and not with ecosystems’ relationships (Fig. 2b).

For the first cluster, biodiversity was ‘Gaia’. For the second cluster, biodiversity was a natural heritage to be preserved, while in the third cluster, biodiversity was the set of living beings and their habits (Fig. 2b).

To what extent are biodiversity portals relevant tools for the teaching-learning process? How do teachers envisage their usefulness and contributions?

About two thirds of the teachers (67%) were using different portals to prepare classes, and more than three quarters (79%) were doing so during classes. Although only six of the 82 spontaneously mentioned portals were related to biodiversity and/or nature conservation, when asked to select portals they knew from a list including ten portals concerning Azorean biodiversity, about half of the teachers (n=125) selected at least one, although more than half selected only one or two portals (2.7 portals in average). The teachers that use biodiversity portals are a small subset of the ones that have heard about them.

To characterize the perspectives about biodiversity portals, these teachers provided 376 response terms, including 150 different words, with an average of 3.1 words per teacher (Appendix S3).

The evocations that constituted the central core of the prototypical analysis focused on generic content, evident on any biodiversity platform; the descriptive contents were frequently associated with portals. The contrast zone combined both the purposes and experience of portal usage. Although it is not common to include user experience in the dominant depictions of biodiversity portals, usage was qualified as positive and accessible. Aspects associated with the evaluation of usability, quality, and certification

294 of portals contents represented 19.7% of the evocations. References to portals as
295 repositories of resources and educational activities were less frequently expressed
296 (11.5%) (Appendix S3).

297 From the similarity analysis, four complementary clusters emerged (Fig. 3b). The term
298 'nature' led the content of the portals related to 'biodiversity', associated in turn with a
299 small cluster of content with a more regional bent (Fig. 3b). A cluster related to the
300 purpose of the portals grouped terms associated with what the portals are for and what
301 they can be used for (Fig. 3b). The cluster led by 'information' represented the type and
302 characteristics of the available contents, moving from the theme of biodiversity to more
303 functional aspects related to accessibility and other attributes of the available knowledge.
304 The fourth cluster specified the evaluation of the portals' contents as a quality resource
305 (useful, updated information, easy to access), although in low frequencies (Fig. 3b).

306 There were significant absences in the evocations regarding the instrumentality of portals
307 for teaching, which is corroborated by teachers' incipient use of the portals (Fig. 3a).

308 Fig. 3

309 When explicitly asked about the type of use teachers make of portals, it is clear that they
310 used them more as a repository of audio-visual (33.5%) and pedagogical (14.9%)
311 resources or specialized information (taxonomic [9.3%], ecological [19.1%], etc.) than as
312 a tool to engage students in teaching activities (14.9%) meant to foster scientific research
313 skills (Table S2a, Fig. S2b).

314 The biodiversity portals were not perceived as being identical nor did they enjoy the same
315 popularity among teachers. The five most referred portals were, in descending order and

316 with frequencies above 14: PARQUESAZ, SIARAM, PBA, REDA and EDUCARAZ (cf.
317 Table S2c). Considering the percentage of evocations related to each portal,
318 PARQUESAZ presented the highest instrumental value due to the available resources
319 (15%), while SIARAM and REDA were, respectively, the portals where quality and
320 usability were more often highlighted (22% each).

321 The content highlighted for SPEA and PBA portals referred to information, , and in the
322 latter its scientific origin; for SIARAM it was regional biodiversity that stood out; for REDA
323 resource diversity and accessibility were emphasized, while the terms ‘conservation’ and
324 ‘environmental protection’ emerged for EDUCARAZ. The attributes assigned to the
325 PARQUESAZ portal exhibited less homogeneity (Fig. S2d).

326 Descriptive statistics show that the biodiversity portals’ users among Azorean teachers
327 did not significantly differ from the teachers that did not use them (Chi^2 (1df)= 0.22;
328 $p<0.63$; Table S3).

329

330 **DISCUSSION**

331 Teachers showed greater fluidity and terminological diversity for the ‘internet’ (n_F=1064;
332 n_A=240) than for the ‘biodiversity’ (n_F=857; n_A=90) stimulus, suggesting that the latter is
333 less accessible to individual consciousness and a more peripheral phenomenon in their
334 social groups. Curiously, the same trend is seen among teachers of exact and natural
335 sciences (n_F=217; n_A=96 vs. n_F=176; n_A=52), despite their specific domain training.

336 Teachers’ visions of biodiversity share some common points with the long-established
337 definition of the concept (CBD 1992), although most focus only on the species dimension.

An incomplete understanding of biodiversity has also been acknowledged by Dikmenli (2010), when studying the conceptual framework of biodiversity on 130 biology training teachers, who however exhibited a more varied and technical lexicon. The multidimensionality of the biodiversity concept is more evident among the training teachers, who included genetic diversity, technological terms, and major scientists, which are absent in our data. Even more sophisticated views on biodiversity were found by Fischer & Young (2007), focusing on notions of balance, food chains and human–nature interactions, and showing desirable or ideal states of nature. This may be related to different methodological devices used, such as focus group discussions and drawings. The diversity of the participants may also have contributed to that conceptual richness. Yet, more than in the previous studies, our results incorporate the ideas of conservation and extinction risk, even if only in the contrast zone, as well as an idea of interdependence between biodiversity and the future and well-being of humanity.

Reviews on biodiversity teaching methods (Navarro-Perez & Tidball 2012, Yli-Panula *et al*. 2018) do not mention strategies focusing on the digital realm; instead, the most common pedagogical methods involve active participation, including experimental work and experiential learning. ICT certainly poses a set of challenges concerning biodiversity teaching. Biodiversity web portals, as sound scientific tools, could link research and teaching, and their contents may support learning, particularly on islands. Additionally, as online free tools, biodiversity web portals are resources easily accessible to both teachers and students, thus serving as mediating instruments between the environment and the quest for knowledge (Flavian 2019). Still, our data reveal that teachers use biodiversity portals mainly to search for images and other audio-visual content. To further clarify the

role web portals may play towards biodiversity education in schools, and ultimately towards biodiversity conservation, the relationship between technology and nature needs further reflection.

Considering that the 'extinction of experience' with nature is fast approaching (Miller 2005, Gaston & Soga 2020), we wonder: can ICTs mediate connection and reconnection with the natural world? Although the positive impacts of technological nature on cognitive functioning and human wellbeing are well documented (Kahn *et al*. 2009), whether 'technological windows' can reconnect people with nature is still under debate.

The dominant view is that 'technological nature' opposes and replaces experiencing 'real nature' in person and *in loco* (Pergams & Zaradic 2006). However, with or without technology, a departure from 'real nature' has already been witnessed. If nature and the internet are useful parts of our daily lives, and if nature does not have to be close to be valued (Clayton 2003), why not take advantage of ICT to promote the connection and reconnection?

Facilitating this type of scenario involves dealing with the problems/limitations identified by research on technological nature (Kahn *et al*. 2009). One of the most relevant caveats regarding technological nature is the lack of differentiation between global and local geographic scale, in the sense that, when experiencing nature through technological windows, people become equally close (Selby & Kagawa 2018). It is therefore worthwhile exploring if biodiversity portals with regional contents may address this risk. Indeed, although we might observe local biodiversity through a technological window, portals may promote nature relatedness via 'zoom lens' allowing a glimpse into an unknown world just in our backyards (Amorim *et al*. 2016).

Given that ICT has the potential to reshape human existence by mediating, increasing or simulating the natural world, biodiversity web portals may constitute relevant tools to raise biodiversity awareness, and even to promote biophilia. However, our data showed that teachers did not acknowledge much usefulness of biodiversity portals.

Portal managers should therefore create, enhance and promote specific pedagogical resources, closely related to school curriculums, and to increase the portals' instrumentality. Thus, to meet teaching and learning needs, resources should emerge from multidisciplinary projects involving teachers, students, scientists and science communicators (Novacek 2008). Furthermore, the development of such pedagogical resources should take into account the importance of message 'crafting', according to people's values and interests, to achieve effective engagement (Coffin & Elder 2005).

Our data show that teachers do not acknowledge many of the dimensions of the biodiversity concept, it also shows that they attribute importance to conservation, and are proficient internet users. Web portals may thus provide teachers with an effective link between the internet and biodiversity, even more given that half of the surveyed teachers are already familiar with several biodiversity portals.

Biodiversity communication in the learning-teaching process must adapt to societal trends and emerging potentialities within ICT. Biodiversity web portals are an example of this potential that has not been fully explored in education and could ultimately help halt biodiversity loss.

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Author contributions

AP, AMA and RG led the writing of the manuscript and performed data analyses. All authors contributed substantially through additions and revisions to the text and gave final approval for publication.

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Conflict of interest

None.

Ethical standards

None.

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Fig. 1 Prototypical analysis of the inductive term 'internet': **(a)** four-box matrix. EO = evocation order; *F* = frequency; **(b)** maximum tree of a similarity analysis of the most frequent evocations (N=243 teachers; 2019). Line thickness and numbers correspond to frequency of co-occurrence; circle size corresponds to word frequency, circle colour indicates evocation order similarity clusters.

Table 1 Data on the evocations for the inductive term 'biodiversity' (n=243); NES, nature exposure scale.

Fig. 2. Prototypical analysis of the inductive term 'biodiversity' categorized: **(a)** four-box matrix. EO = evocation order; *F* = frequency; **(b)** maximum tree of a similarity analysis of the most frequent evocations (N=234 teachers; 2019). Line thickness and numbers correspond to frequency of co-occurrence; circle size corresponds to word frequency, circle colour indicates evocation order similarity clusters.

Fig. 3. Prototypical analysis of the inductive term 'web portals related to biodiversity': **(a)** four-box matrix. EO = evocation order; *F* = frequency; **(b)** maximum tree of a similarity analysis of the most frequent evocations (N=117 teachers; 2019). Line thickness and numbers correspond to frequency of co-occurrence; circle size corresponds to word frequency, circle colour indicates evocation order similarity clusters.